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OF

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CONTENTS:

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ABSTRACT OF PROCEEDINGS.

March 3, 1890. Meeting called to order by the President, at 19.45 o'clock, 22 members present. Committee consisting of Messrs. Jacoby, F. E. Fisher and Coxe, appointed to revise the Constitution. Messrs. Knapp, Winfree, McClurg, Barrios, Hayes, Chao, Heindle, elected members. Papers were read by Mr. Barrett on "The Bethlehem Stand Pipe;" by Mr. Phillips on "The Water Supply of Washington; by Mr. Baily on "The Rainfall at Bethlehem."

April 1, 1890. President in chair at 19.45 o'clock, 32 members present. Messrs. Paine, Vander Horst, Stilson, Schmitz, Doolittle, Zimmerman elected members. Prof. Merriman addressed the Society on "Nationalism and Engineering," for which a vote of thanks was given. Mr. Potter gave a short description of the Sing Sing Water Works.

F. E. FISHER, Sec'y.

ELECTRO-METALLURGY.

Metallurgy is the art of extracting metals from their ores and bringing them into that state of purity which is necessary for their industrial application. Electro-Metallurgy is that branch of the metallurgic art in which the agency of electricity is employed. We would then define Electro-Metallurgy as the art of extracting metals from their ores or of refining them, on a commercial scale, by the agency of the electric current. This art approaches very

closely to that of Electro-Deposition, but we may easily keep them distinct by limiting the scope of the latter to the deposition, by elecricity, of thin sheets of a metal to serve the purpose of a plating.

Electro-Metallurgy falls naturally into two divisions:

1. Extraction of metals from their ores by electricity.
2. Refining of metals by electricity.

This paper will treat more closely of the first of these divisions, a subject which has only risen into prominence during very recent years, while the latter divisions will be only incidentally touched upon.

The successes of electro-metallurgy all date from the invention of the magneto-electric machine. The principles of electric decomposition and deposition, especially from aqueous solution, were well known for many years; but, the only available source of the electric current was the battery, and many promising processes were worked out and all ready to be applied industrially as soon as a cheaper source of electricity was discovered. The introduction of Wilde's magneto-machine in 1865, may be taken as the starting point of all our commercial electro-metallurgic success. The case of the refining of copper furnishes a good illustration of the above statements. As early as 1847, Maximilian, Duke of Leuchtenburg, made an investigation of the action of the battery on impure copper, finding out that very pure copper could be obtained and all the precious metals left undissolved in a condensed form ready for further treatment. Since he used batteries to furnish the current, the application of these principles on a commercial scale was impossible. But, in 1865, immediately on the introduction of Wilde's machines, Mr. Elkington started a plant for refining copper, which has been in successful operation ever since. With greatly improved electric machines, constructed to furnish currents of any desired force or quantity, and especially with water power used to operate them, the cost of these electric operations has been very greatly reduced and their commercial development made possible.

Metallurgically, there may be distinguished three distinct methods of applying the electric current to the extraction of metals from their compounds or ores:

I. Electro-deposition from aqueous solution.
II. Electro-deposition from a fused electrolyte.
III. Electro-thermal reduction.

I.

This heading includes the greater number of electro-metallurgic processes. The method has been principally applied to the metallurgy of copper, silver, gold and zinc, and has developed on two distinct lines—

1st. Preparation of a solution of the metal and electrolysis of this by means of insoluble anodes or anodes of a metal other than that being deposited.

2nd. The use of anodes made of the metallic compound, the solution being regenerated by the acid set free attacking these anodes and dissolving out the metal.

Operations of the first class are particularly applicable to the isolation of copper or zinc, which are easily brought into solution. Copper exists as sulphate in many mine waters, which need only to be concentrated by evaporation to be ready for treatment. Many of the ores of copper can be treated so as to pass into soluble sulphate. Thus, if copper pyrites is carefully burnt, most of the copper will form sulphate, and can be washed out of the residue. Oxide or carbonate ores can easily be brought into solution by treatment with sulphuric acid. When a solution of copper sulphate thus formed is electrolysed, using sheet iron anodes and sheet copper cathodes, copper is deposited on the latter, while the anodes are dissolved and ferrous sulphate goes into solution. When all the copper is deposited, the solution can be evaporated and the sulphate of iron produced used over in the roasting operation, converting copper oxides into soluble sulphate. This electrolysis is often performed without the aid of an outside current, the copper and iron electrodes being simply connected by a wire outside of the bath, the electricity generated by this galvanic couple being sufficient to perform the electrolysis.

Zinc ores can in a similar manner be brought into solution. Letrange's process consists in taking zinc sulphide (blende,) roasting it so as to convert as much as possible into sulphate, and leaching the product. Some zinc oxide will also be formed and remain undissolved in the residue. The solution of zinc sulphate is electrolysed by using a thin plate of zinc for cathode and a lead plate for anode. The lead being insoluble in sulphuric acid, the solution becomes acid as the zinc is deposited. The acid solution is gradually removed and regenerated by passing it over the residues left from the first washing of the roasted ore. The acid then dissolves out the zinc oxide.

The use of metallic compounds for anodes affords a direct method of extracting from the ore in a minimum number of operations. Thus, in Luckow's zinc process, a bath is made of a solution of zinc sulphate, the cathode is a zinc plate, and the anode a mixture of zinc ore and coke, finely powdered and held in an open-work case. In Marchesi's copper process, the anode is copper matte, cast into the form of slabs and used exactly as if they were impure copper. One of the chief advantages thus gained is that the precious metals remain undissolved and fall to the bottom of the bath.

If impure copper or lead containing gold and silver are thus treated, the precious metals are entirely recovered. In the case of copper, the bath used is copper sulphate solution; in the case of lead it is a dilute solution of lead sulphate in acetate of soda. Gold and silver may thus be profitably extracted from copper or lead which could not be treated by any other process of separation. These processes are the basis of the work done at all the large electrolytic copper establishments, such as Balbach's, at Newark, N. J., the North German Refinery, at Hamburg, at Biache, Marseilles, Oker, etc.

II.

About 1854, Bunsen performed the electrolysis of a bath of fused, anhydrous magnesium chloride, and thus obtained that metal. In 1854, Deville electrolyzed in a similar manner the anhydrous double chloride of aluminium and sodium, and thus obtained the first masses of aluminium ever seen. In carrying out these experiments, the electrodes were either compact carbon rods, in which case chlorine was evolved at the anode, or the latter electrode contained both carbon and magnesia (or alumina), made by mixing the earth with pitch, moulding it into shape and coking it. The salt was melted in a crucible set in a furnace, the electrolysis taking place at perhaps 500° to 800°. The greatest practical difficulty was the disintegration of the electrodes, particularly the anode. Since a battery was used, the method was not applied commercially until many years after, but, of recent years dynamo-electric machines have been applied aud these methods greatly developed.

Large quantities of magnesium are now being made very cheaply in Germany by the Aluminium und Magnesium Fabrik at Bremen, the method used being electrolytic and on the above

described principles. Dr. Kleiner's process for producing aluminium consists in fusing cryolite (a double fluoride of aluminium and sodium) between two carbon electrodes, the bath being kept in fusion by the heat of the electric arc and the aluminium being produced by electrolysis. Mr. Hall of Pittsburgh dissolves alumina in a bath of aluminium, sodium and calcium fluorides, and electrolyses it using the carbon lining of the iron pot holding the bath, as the cathode, and carbon rods dipping in the bath as the anode, the distance between these poles being regulated, so that there is sufficient heat generated to keep the bath fluid. In this case, if the strength of the current is carefully regulated, the alumina dissolved in the bath is decomposed without the other solvents being affected.

This method of electrolysis has also been applied by M. Jablochoff to the isolation of sodium. The bath in this case is molten sodium chloride, the electrodes made of carbon, and arrangements made to feed the bath as it is used up. The electrodes are encased in tubes, the negative one connecting with a condenser in which the sodium vapor condenses, for the sodium volatilizes at the temperature of the bath; the tube from the positive pole conveys away the chlorine gas, which is valuable for use in making bleaching powder.

III.

The electro-thermal processes are primarily dependent on the utilization of the enormous temperature of the electic arc, by interrupting a powerful current, by this agency bringing about a chemical reaction which would not take place at a temperature attainable by any other means.

Siemen's steel melting furnace was probably the father of these processes, as it showed what thermal possibilities lay in this direction. The advantages of reduction in an enclosed space thus heated are that the atmosphere is perfectly reducing and the temperature almost unlimited. The electric furnaces so far devised, have been used principally for reducing alumina and silica and producing aluminium and silicon bronzes.

Cowles' electric furnace consists of a horizontal fire-brick-lined cavity, in which the mixture for reduction is placed and through the ends of which pass two large carbon electrodes. The charge is usually carbon, alumina and granulated copper. The furnace is covered with a fire-clay slab. On passing the current from a

300 H. P. dynamo machine, and gradually drawing the electrodes apart, an interrupted arc of several feet in length is obtained, and at the temperature obtained alumina melts, copper vaporizes, carbon crystallizes, and alumina is reduced by carbon. The product is aluminium bronze.

Heroult's furnace works on a similar principle, but is arranged differently. A large iron case is filled with carbon, a cavity hollowed out on top and a large carbon electrode hung so as to dip into this cavity. On placing copper in the hole, the iron case being connected with the negative pole of the dynamo, the arc formed between the carbon rod and the copper soon melts the latter. Then alumina is thrown in, and is also liquified by the arc. The operation then proceeds as if it were the simple electrolyses of a fused bath, the copper being the negative electrode and the fused alumina the electrolyte. Aluminium being set free, the copper absorbs it and forms aluminium bronze.

CALCULATIONS.

Having briefly reviewed the various kinds of electro-metallurgic proçesses, we will note, by means of a few illustrations, the method of calculating the amount of power required to decompose compounds by electrolysis, and thus obtain means of estimating the percentage of useful effect in any process for which we have the necessary details.

An electric current has two factors — quantity and intensity; the former measures its absolute amount, the latter its power of overcoming resistance. The unit of quantity is an ampere (measured on an ampere meter), the the unit of tension is a volt (measured by a voltameter.) Whether the affinities of a chemical compound will be overcome by a given current, will depend on whether the current is of sufficient *tension;* when a current is of this required tension, the amount of chemical action performed will be proportional solely to the *quantity* of the current. The dynamic energy of an electric current is proportional to the product of its quantity by its tension; *i.e.*, a current of one ampere at a tension of one volt has a definite mechanical value, and if this force is exerted in one second, the unit is called a Watt. This unit is at the foundation of all our subsequent calculations, and its absolute value is of first importance. The mean of the best experimental determinations make one Watt equal to 0.00024 calories of heat or to 0.1 kilogrammeters of work, and therefore nearly 1-750th of a horse-power.

As before stated, the chemical work which a current will do depends solely on its quantity, assuming that it is of intensity sufficient to decompose the compound. Some experimental data are therefore needed here, and they are based on the determination that when an electric current is decomposing water, each ampere passing produces 0.00001035 grammes of hydrogen. The amount of oxygen liberated at the same time is *necessarily* eight times as much, and we therefore can pass directly to the law that the amounts of different elements liberated by a current of given quantity is proportional to their chemical equivalents. The amount of any element set free by one ampere is its electro-chemical equivalent.

The question of the tension necessary to decompose a compound follows immediately the statements of the two preceding paragraphs. To liberate 0.00001035 grammes of hydrogen from water requires an expenditure of energy represented by 0.00001035×34.162 or 0.000358 calories. But, a current of one ampere at a tension of one volt represents only 0.00024 calories, and therefore, the work being done in decomposing the water absolutely requires that the strength of the current shall be at least $\frac{0.000358}{0.00024}$ or 1.49 volts. This is the *absolute minimum of electro-motive force* necessary for *decomposing* water. The tension practically required will always be somewhat larger than this for the reason that the transfer resistance of the electrolyte must be overcome, *i.e.*, the resistance which the current meets in passing from one electrode to the other. This quantity will vary with the temperature of the bath (as far as it affects the conductivity of the electrolyte) and the distance of the electrodes apart.

A careful application of the principles just illustrated will enable us to discuss many of the problems presented in electro-metallurgy. In order for the electrolysis to take place at all, it is necessary that the electrolyte be in a fluid state, and that it be a conductor of electricity. These conditions being filled, and proper electrodes put in place, then the current passing between the electrodes must be of a certain minimum tension to accomplish decomposition. The following examples will show the manner of making the calculations.

In producing sodium electolytically, the bath used is fused common salt. The voltage absorbed by a bath is about 12 volts, varying with the temperatnre of the bath and the distance of the

electrodes apart, and with a current of 70 amperes (per second) the amount of sodium obtained averages 39 grammes per hour. The latter quantity shows a yield of $39 \div 60 \div 60 \div 70$ or 0.000155 grammes of sodium per ampere, and since the electro-chemical equivalent of sodium is 0.000238 grammes (0.0001035 $\times$ 23), we see here that about 65 per cent. of the sodium liberated by the current is practically obtained; the other 35 per cent. is really set free, but is lost by re-combination with chlorine in the bath, or oxidation, or imperfect condensation. But, this cannot be the only source of loss in the process, for a current of 70 amperes and 12 volts represents $70 \times 12 = 840$ Watts or 0.205 calories; the liberation of 39 grammes of sodium from sodium-chloride (heat of combination 4.2474 calories per gramme of sodium) represents only $39 \times 4.2474 = 165.65$ calories per hour or 0.046 calories per second. The net proportion of useful effect in the operation is therefore only 22.5 per cent. The cause of this very low return we can find in the high voltage used (12 volts). If we calculate the minimum electromotive force necessary to decompose sodium chloride we have (multiplying the electro-chemical equivalent of sodium by the heat of combination of one gramme of sodium when forming its chloride, and dividing by the heat equivalent of 1 Watt)

$$\frac{(0.00001035 \times 23) \times 4.2474}{0.00024} = \frac{0.001011}{0.00024} = 4.2 \text{ volts.}$$

Since then, only 4.2 volts out of the 12 volts absorbed by the bath are used for actual decomposition, the percentage of the power of the current utilized in this way is 35 per cent. Since only 65 per cent. of the sodium liberated is actually obtained (as before calculated), the net result over all must be 65 per cent. of 35 per cent., or 22.75 per cent., thus agreeing with the result before obtained.

A current of 70 amperes and 12 volts is 840 Watts, or about 1.12 horse-power. The power required to drive a dynamo to supply this current would be about 1.5 H. P., allowing 75 per cent. as the efficiency of the dynamo. Assuming 2 kilos of coal burnt under the boilers per indicated horse-power per hour, this would require 3 kilos of coal per hour; and if the calorific power of the coal is 9000 calories, the heat energy expended is about 27000 calories per hour. This produces 39 grammes of sodium, representing in its isolation from chlorine 165.6 calories. The sodium produced represents therefore only 0.6 of one per cent.

of the energy contained in the coal used. Of course, sodium is a difficult metal to handle, and these results are much inferior in effeciency to what are obtained in producing magnesium and aluminum from their fused salts, while the maximum efficiency is attained in the electrolytic processes from acqueous solution. The above calculations in regard to sodium are given simply as an example of how the principles of electrolysis can be applied to discussing the efficiency of electro-metallurgical processes.

In those methods classed as electro-thermal, it can be proved that the reduction is chiefly by chemical action, since the quantity of the currents used (in amperes) is not sufficient to account for more than a fraction of the yield of metal actually obtained. The currents are in these cases principally utilized as sources of intense heat, under the action of which unusual chemical reactions can be made to take place.

In conclusion it might be said that aluminium is profitting more than any other metal by the application of numerous electrolytic methods to its industrial manufacture. But, if ever the problem of converting the energy contained in coal directly into electric energy be solved, there are very few of the metals which may not be cheapened by electrolytic methods. If the conversion could be accomplished with an efficiency of only 50 per cent., it would still be 10 or 15 times as efficient as our present indirect methods of boilers, engines and dynamos, and the possibilities opened out for the art of electro-metallurgy by such a cheapening of cost of the electric current are so extensive that for fear of being styled visionary we will forbear any further speculations.

JOSEPH W. RICHARDS.

WASHINGTON CITY WATER SUPPLY.

Regardless of population there is no city in the world that consumes so much water *per capita* as Washington. With an urban population somewhat less than two hundred thousand, the average daily consumption for the last fiscal year, ending June 30, 1889, was very nearly thirty-one million gallons; or about one hundred and sixty gallons for each person. This is considerably less *per capita* than is given by J. T. Fanning for 1882, in his "Hydraulic and Water Supply Engineering," which is to be accounted for as follows: (1) Mr. Fanning seems to have failed to include in his estimate the annexed suburban town now

known as West Washington, which had at that time a population of about fourteen thousand, and obtains its supply from the same distributing reservoir, where the gauge measurements to determine the consumption are taken; and (2) the average for that year was phenomenally large, as is shown by the following table:

AVERAGE DAILY CONSUMPTION OF WATER FOR THE PAST 15 YEARS.

Year.	Gallons.	Year.	Gallons.	Year.	Gallons.
1875	21,000,000	1880	25,740,138	1885	25,218,194
1876	24,177,797	1881	26,525,991	1886	25,542,476
1877	23,252,932	1882	29,727,864	1887	26,878,424
1878	24,885,935	1883	24,314,715	1888	29,115,774
1879	25,947,642	1884	24,827,013	1889	30,751,315

This amount *per capita* exceeds that of any other American city by nearly twenty per cent., and that of any modern European city quite three fold. Such an enormous consumption has been explained as due to the great amount of water used in sprinkling the wide asphalt paved street, the public parks and private lawns and terraces, which are the distinguishing features of this beautiful city, and in the play of public fountains and the use of public buildings. But the statistics of the Engineer's office do not confirm this explanation as even approximately adequate; and of the few manufactories in the city using water power, none derive their supply from the public reservoirs. The reports of the Engineer's office show the daily consumption throughout the Winter months, when street and park sprinkling and the play of fountains is necessarily almost entirely suspended, to be considerably greater than during the Summer months when the amount used for these purposes is a maximum. They show further that in the twelve hours from 7 A.M. to 7 P.M., about sixty percent. of the total daily consumption is used, yet during this time neither are public fountains, nor street sprinklers, nor park or lawn sprinklers frequently in operation. The public buildings require little water more than is used in wash rooms and for steam heating, which is no considerable portion of the supply. Allowing a fair estimate for the amount due to leakage in the mains, which cannot be directly ascertained, the conclusion must be, therefore, that the far greater part of this remarkably large consumption is actually used for domestic purposes in the private houses. A consideration of the sewerage system of the city, the sanitary arrangements of the houses, and the general character of the population will render this even more apparent.

Washington derives its water supply from the Potomac River. The water is taken from the river at a point just above Great Falls, about sixteen miles from the city. Here the Government has constructed an expensive masonry dam, (completed August 21, 1886) entirely across the river to a height of 148 feet above the datum plane of mean tide at the Washington Navy Yard, in front of the city, which insures a constant supply at all seasons of the year. This dam is 2877 feet in length, 4 to 20 feet in height and cost $125,000. The feeder entrance to the aqueduct has an elevation at the top of 149 feet, and at the bottom 139 feet above datum. The water passes through a gate house into the aqueduct proper, which is circular of brick masonry, composed of three 4-inch rings set in hydraulic cement and is 9 feet in interior diameter. The elevation of the centre at the origin is 146.5 feet above datum, with a slope of .00015 or 9½ inches to to the mile. Its length to the receiving reservoir is 48195 feet or about 9 miles.

The receiving reservoir hardly deserves the name of reservoir at all. It is merely an irregular natural valley through which flowed a small stream called Powder Mill Branch, and across which an earthen dam has been thrown. It is without slope paving of any kind, and the drainage of all the adjacent country pours into it without hindrance, and vegetation is allowed to thickly cover its banks. Although its capacity is given as about 150,000,000 gallons, it is exceedingly shallow in places and has an average depth of hardly more than eight or ten feet with an area of 50.65 acres.

The elevation of the centre line of the conduit discharging into this reservoir is 139.37 feet above datum. The distance from this point to where the conduit emerges from the reservoir is 3550 feet. The aqueduct continues 10,150 feet or about 2 miles to the distributing reservoir on the heights just west of the city, which it enters at a height above datum of 137.36 feet. This reservoir has a capacity of 170,000,000 gallons and an area of 36.75 acres and is well constructed and cared for, in every particular. From this point the water is supplied to the city by means of three iron mains of 36, 30 and 12 inches diameter.

With the great increase in population and even greater increase in the water consumption, it became necessary to augment the resources of distribution. The nine foot conduit brought an ample supply to the distributing reservoir, but the three small

mains were becoming entirely inadequate to meet the demands, and moreover so reduced the effective head by friction and other losses, as to render the supply in the more elevated portions of the city exceedingly precarious and irregular: a source of danger to public health and to the security from fire. To this end Congress, in 1882, passed an act directing the Secretary of War "To extend the Washington aqueduct from its present eastern terminus to the high ground north of Washington near Sixth Street extended, and that he construct at that point a reservoir of the capacity of not less than 300,000,000 gallons, and lay such main connections as may be necessary to furnish to Washington and Georgetown (now West Washington) an ample supply of water."

The plan proposed, and approved by this act, (of July 15, 1882) for the extension of the aqueduct, was submitted by the Engineer Commissioner of the District of Columbia, and involved the construction of a tunnel 20,700 feet long. The project being to dig down deep into the solid rock and then tunnel through, thus doing away with any lining whatever and insuring a safe and nearly uniform grade. For this work $599,534.55, the estimated cost, was appropriated by Congress and work immediately begun.

The alignment was carefully made by a civil engineer* employed for the purpose, and the contract for the entire work was let to Beckwith and Quackenbush, of New York. Four working and four air shafts were sunk to an average depth of about 160 feet. The normal section of the tunnel was rectangular, 11 feet wide and 7½ feet high, the area of excavation being 82.5 square feet. A determination of the character of the rock encountered, was not obtained until 1886, when nearly ninety-five per cent of the entire tunnel had been excavated and nearly two years after the work had been begun.† Analysis then showed it to be a compact micaceous schist, containing many elementary causes of degeneration, including iron pyrites, impure mica and magnesium silicate in talcose forms.

At first the rock was thought to be amply strong to withstand the wear and pressure of the estimated head of water of nearly two hundred feet; but as the work progressed it was found to crumble

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* Mr. George H. Coryell, who had immediate charge of operations as assistant engineer.

† Special report of the Curator of Lithology in the National Museum, dated January 20, 1886.

and decrepitate under the action of the air to such a serious extent, that the conclusion reached when the "holing" was about half completed was that a large part of the tunnel would require lining. This led to difficulties with Congress regarding the additional appropriations, and a consequent suspension of the work. After a long and searching congressional investigation, work was finally resumed and the lining commenced. Experience having abundantly shown that the rock decrepitated rapidly under the action of the air, but remained, comparatively unchanged in water, it is amusing to note, that Congress was prevailed upon to appropriate $5000 for pumping, to keep the tunnel dry during this long delay, when it would have filled with water, and thus expense was not spared to do as much damage as possible.

August 4, 1886, Congress appropriated $395,000 for the purpose of lining where necessary, and completing the entire work. The plan adopted was to line with a 13-inch (3 brick) arch, and fill in solidly with dry stone between the brick and the rock in place; but this was afterwards modified on recommendation of the Board of Engineers, U. S. A., by filling in with rubble laid in cement instead of dry stone, on the ground that "no movement can be permitted among the stones which are to transmit the ultimate pressure to the rock in place, and this can only be accomplished by filling up the interstices with a solid mass." The supplementary contract for this work, as well as for the necessary excavation, was let to the contractors who had conducted the entire work from the beginning.

Wherever the lining was introduced it necessitated an enlargement in section from 82.5 square feet, to 109.67 square feet, 143.4 square feet, or 167.3 square feet; the first where no timbering was required, the second where only side timbering was employed, and the third where both side and top timbering was needed. These were the limits at which the contractors were required to work and for which they were paid, but the actual section was in each case frequently much greater, owing to the irregular breaking of the rock beyond the required limits.

By the end of the fiscal year, June 30, 1888, the "holing" of the tunnel had been completed, and 6,110 feet, or nearly one-third, lined. It had already been deemed necessary to complete the lining throughout and an additional appropriation (March 30, 1888) of $355,000 had been obtained from Congress for this purpose, with the extraordinary condition attached thereto, that "all

of said work is to be completed by November 1, 1888." Additional contracts were let, and the work pushed forward as rapidly as possible.

Let us now look back at the enormous appropriations made from time to time for this work. It is to be remembered that no extraordinary difficulties involving additional expense beyond the original estimates, had been encountered in any portion of the work, save the matter of lining. And yet this utter inadequacy of the original estimates, which would be so surprising if from a civil engineer, even in work of this character, is of common occurrence in the designs of army engineers, who indeed seldom complete their work within their original estimates.

Original estimate, July 15, 1882, .	$ 599,534 55
(Pumping) special, Mar. 26, 1886, . .	5,000 00
Estimate, Aug. 4, 1886, . .	395,000 00
Estimate, Mar. 30, 1888, . .	355,000 00
Total, ...	$1,354,534 55

Of this amount, June 30, 1888, there had been expended $1,011,873.36, leaving a balance available of $342,661.19, which was deemed sufficient for the completion of the work in all its details by the engineer in charge, Major Lydecker.

In making further contracts for the completion of the lining, Major Lydecker seems to have realized that no further appropriations were to be obtained from Congress, and he made his provisions accordingly. The contractors were no longer to be paid per cubic yard for the extra excavation, brick masonry, concrete masonry or the rubble packing, but a rigid compensation per linear foot of the tunnel was agreed upon, as the following extract from his contract with Beckwith and Quackenbush, shows:

"It is further agreed that payment for the aforesaid work of lining shall be as follows: For full lining of 1st class, forty dollars ($40) per linear foot of tunnel so lined; for lining of 2d class, twenty-four dollars and fifty cents ($24.50) per linear foot of tunnel so lined; for lining of 3d class, twenty-eight dollars and fifty cents ($28.50) per linear foot of tunnel so lined. The prices aforesaid being no greater than those allowed under the contract under which work has heretofore been done on the tunnel, and such as will insure the completion of the work within the limits of the sum appropriated therefor. It is expressly understood that the prices

paid as above include compensation for all work and material necessary for the solid lining of the tunnel in the several classes, as well as the work of enlarging the tunnel from the normal cross-section to that required for placing the designated lining."

It is to be observed that there was no provision made for extra compensation for the filling of unusual cavities that sometimes occured, many cubic yards in extent; and the contractors could have no other motive than to complete the work at the least possible cost to themselves, and hardly more thoroughly than strict and faithful inspections by the engineer's assistants would compel. This plan of a rigid compensation would cause them to hasten the work as much as possible without moving a foot of earth or stone more than was necessary. But it was inherently bad in principle, because it tempted them to neglect to do their work faithfully wherever they could escape the probability of detection, and this, indeed, was what actually happened. The government inspectors did not do their duty, the visits of the engineer in charge, were made at intervals of several months, and the contractors did as the pleased. The work was rushed forward without paying any attention to the backing of the arches; huge spaces were left behind the lining wherever they occurred, and where any packing was inserted it did not at all conform to the requirements of the contract.

Rumors of all this developed several sensational articles in the local papers and finally Congress took up the matter, and after considerable discussion a board of inquiry was appointed to investigate the charges that had been made. The contractors were found guilty of a breach of contract, and of giving and the inspectors of taking bribes; the engineer was found guilty of neglect of duty, relieved from further charge of the work and sentenced to a slight temporary reduction in salary; and after taking a large amount of expert testimony and reviewing the whole undertaking in all its details, it was finally determined to abandon the tunnel altogether. And thus after an expenditure of $1,100,000 the city was left no better off than before, for its water supply.

It is a serious engineering problem as to whether the total abandonment of the tunnel after this enormous expenditure was not a most extravagant mistake. The work of tunneling had been completed, and the work of lining nearly so, only a comparatively small portion of which was seriously defective. The tunnel was open and free from any considerable obstruction

throughout its entire length. It had been allowed to fill with water to the surface level of the shafts, thus giving a pressure head of nearly one hundred feet, to remain for several weeks, and then pumped out and found to be free from any serious breaks, fractures or injury of any kind.

Meanwhile the reservoir had been completed and awaited a conduit connection. Again plans had to be submitted to Congress for this work. But there, the word "tunnel" was held in very bad repute and something new had to be proposed. So the engineer, who had succeeded Major Lydecker, recommended putting in an iron main, 48 inches in diameter at an estimated cost of $575,000. This involved the tearing up of miles of expensive street pavements and the consequent inconvenience of traffic, and at best would only provide a temporarily adequate supply. But it met the approval of Congress and a bill was passed March 2, 1889, appropriating the amount specified. Work was immediately begun and at this time is well toward a successful completion. The pipe is cast iron, hub and spigot joint, and it is estimated it will increase the supply to from forty to fifty million gallons per diem, an amount considered ample to meet all demands for the next ten years.

ASA E. PHILLIPS.

PRECIPITATION AT BETHLEHEM, PA.

This article is intended as a continuation of the one which appeared in the JOURNAL a few years ago.* The tables therein appearing have been extended to date.

The observations on the precipitation at Bethlehem were taken by Mr. J. E. Luckenbach, to whom thanks are due for the data given below. His pluviometer consists of a galvanized iron cylindrical vessel twelve inches deep by ten inches diameter, placed at the surface of the ground twenty feet from his house, and therefore free as far as possible from eddies. His gaugings commence in July 1877, the rainfall for the last six months of that year being as follows: July, 6.50 inches; August, 6.64; September, 3.23; October, 6.31; November, 5.40; December, 1.60; total 29.68 inches. In all the tables the snow is melted

* "Rainfall at Bethlehem, Pa," by Mason D. Pratt, Volume I, No. 4.

and included with the rain. Unfortunately no separate records were kept of this snow-fall.

Below is given a table of the monthly rainfall from January 1878 to January 1890 with the monthly and yearly means.

	1878	1879	1880	1881	1882	1883	1884	1885	1886	1887	1888	1889	Monthly Mean.
Jan.	4.52	0.00	2.95	4.06	3.32	4.32	2.39	4.43	3.63	3.62	5.09	4.66	3.583
Feb.	3.25	1.23	2.86	2.43	3.90	4.04	4.85	3.65	4.69	5.47	3.51	1.94	3.485
Mar.	2.75	3.41	4.13	5.48	4.91	2.71	5.04	1.04	4.08	1.86	3.84	3.35	3.550
Apr.	2.92	3.98	3.50	0.99	2.19	2.79	2.41	2.36	2.98	2.08	3.31	4.30	2.817
May	4.65	2.17	1.26	2.87	6.58	2.88	2.86	2.29	5.59	1.96	2.84	4.30	3.354
June	3.50	8.38	3.88	6.08	3.28	8.62	4.76	1.06	4.53	5.70	3.12	5.28	4.849
July	5.28	4.04	4.17	1.36	2.77	4.52	8.13	2.76	3.52	8.58	2.64	9.93	4.808
Aug.	2.03	6.03	2.50	0.59	3.54	1.55	2.49	9.17	2.15	3.47	9.20	4.10	3.902
Sept.	2.49	1.90	2.47	0.90	5.25	4.20	1.03	0.55	1.77	2.78	10.93	6.14	3.367
Oct.	3.40	0.81	1.85	2.90	2.70	5.16	3.64	4.92	2.19	1.12	2.77	3.29	2.896
Nov.	3.44	1.84	2.73	2.72	1.32	1.55	2.71	4.28	5.44	1.32	3.82	8.72	3.324
Dec.	5.60	5.54	1.71	4.61	1.62	2.59	6.05	1.60	3.66	5.11	3.60	1.67	3.613
Ann'l Rain-fall.	43.83	39.33	34.01	34.99	41.38	44.93	46.36	38.11	44.23	43.07	54.67	57.68	43.55

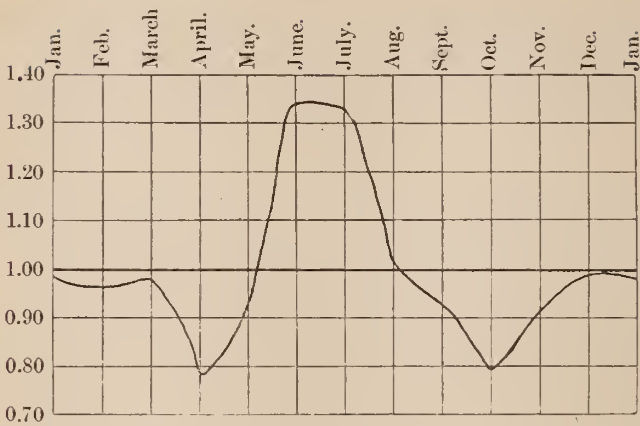
This yearly mean is 43.55 inches, and attention must be called to the excessive falls of the last two years, 54.67 inches for 1888 and 57.68 inches for 1889; 1880 was the year of minimum fall, with 34.01 inches. A glance at the monthly means will show that April is our dryest month, with October a close second in dryness. June and July are the wettest months. The monthly distribution may be better appreciated by an inspection of Fig. I.

In September, 1888, occurred the largest monthly rainfall recorded, 10.93 inches; August of the same year gave 9.20 inches, and July, 1889, deluged us with 9.93 inches. Looking at the monthly means of those months, we see how far these are in advance of their mean values.

The mean monthly precipitation being 3.63 inches, the table below gives the monthly means with their ratios to this, from

MONTH.	Jan.	Feb.	Mar.	Apr	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Mean Precipitation.	3.58	3.48	3.55	2.82	3.35	4.85	4.81	3.90	3.37	2.90	3.32	3.61
Ratio.	0.986	0.959	0.978	0.777	0.923	1.336	1.325	1.074	0.928	0.799	0.915	0.994

which ratios the curve (Fig. I) was plotted, using the months as abscissas and the ratios as ordinates.



The following table gives the number of days since 1880 on which rain has fallen. The yearly mean total is 89.6 days, while in 1888 rain fell on 101 days and in 1889 on 114 days, a very

	1881	1882	1883	1884	1885	1886	1887	1888	1889	Mean.
January	3	5	8	9	5	10	7	9	8	7.1
February	3	6	9	8	6	8	10	7	6	7.0
March	5	6	4	6	5	11	5	7	7	6.2
April	2	4	6	4	8	9	11	4	8	6.2
May	7	11	9	8	8	12	6	15	9	9.4
June	11	7	7	6	6	9	11	8	10	8.3
July	5	4	9	8	10	10	13	9	12	8.9
August	3	6	3	7	9	5	11	10	9	7.0
September	3	6	6	3	5	5	7	9	16	6.7
October	8	5	8	10	7	9	6	10	9	8.0
November	7	5	5	5	10	10	4	7	11	7.1
December	7	5	8	7	8	12	8	6	9	7.7
Total	63	70	82	81	87	100	99	101	114	89.6

great excess. On an average May has the greatest number of rainy days, 9.4, July next, 8.9 days, June next with 8.3 days, giving May, June, and July as the months with the greatest number of rainy days. In September, 1889, it rained during 16 days, thus breaking tne record.

Since 1880 the following rain-storms of more than one inch have occurred, their dates and amounts being given. March 12, 1888, we have recorded 1.44 inches of rain, which is equivalent to about 16 inches of snow, this being the first day of the great blizzard which commenced Sunday evening, March 11th. On May 31, 1889, occurred the great Johnstown flood; it will be remembered that on that day there was a slight fall here; the storm reached Bethlehem next day and gave us about one inch. The greatest storm recorded occurred January 26 and 27, 1883, with 6.46

Date.	Amount.	Date.	Amount.	Date.	Amount.	Date.	Amount
1881.	Inches.	1884.	Inches.	1886.	Inches.	1888.	Inches.
Jan. 10	2.45	Feb. 28	1.08	Apr. 7	1.10	Sept. 8	1.36
Jan. 21	1.06	Mar. 9	1.77	May7&8	2.83	Sept. 11	1.86
Feb. 11	1.13	Mar. 19	1.26	May 13	1.58	Sept. 18	4.70
Mar. 9	1.36	Apr. 9	1.19	June 14	1.11	Oct. 27	1.11
Mar. 19	1.33	Jun.25&26	4.22	June 23	1.56	Nov. 15	1.23
Mar. 31	1.39	July 4	1.50	July 10	1.24	Nov. 19	1.17
May 6	1.07	July 5	1.07	Aug. 6	1.12	Dec. 17	2.28
June 27	1.54	July 11	2.71	Oct. 27	1.53	1889.	
Dec. 1	1.13	July 27	1.00	Nov. 18	1.49	Jan. 17	1.18
Dec. 22	1.05	Oct. 29	1.20	Nov. 25	1.25	Jan.20&21	1.29
1882.		Dec. 6	2.10	Dec. 31	1.10	Mar. 3 & 4	1.21
Jan. 21	1.05	Dec. 14	1.05	1887.		Apr. 28	2.12
Feb. 21	1.34	1885.		Jan. 14	1.22	May 20	2.18
Mar. 1	2.16	Jan. 6	1.38	Feb. 18	1.17	May 27	1.02
Mar. 27	1.00	Jan. 11	1.27	Feb. 26	1.42	June 1	1.01
June 26	1.02	Feb. 9	1.52	Mar. 22	1.02	June 26	1.79
Sept. 11	1.04	Feb. 16	1.26	June 23	1.94	July 11	1.64
Sept. 22	1.37	Apr. 4	1.08	July 23	1.35	July30&31	2.72
Sept. 26	1.30	Aug. 1	1.18	July 31	1.00	Aug. 14	2.52
1883.		Aug. 3	4.45	Aug. 22	1.01	Sept. 18	2.16
Jan. 13	1.00	Aug. 7	1.10	Sept. 12	1.78	Oct. 27	1.96
Jan. 20	1.00	Oct. 21	1.65	Dec. 18.	1.86	Nov.2&3	1.07
Feb. 14	1.07	Nov. 2	1.08	1888.		Nov. 9	1.44
Apr. 23	1.08	Nov. 9	1.01	Jan. 1	2.38	Nov. 10	1.26
June 18	1.00	1886.		Mar. 12	1.44	Nov. 27	1.63
Jun.26&27	6.46	Jan. 4	1.75	Mar. 26	1.18		
July 15	1.92	Feb. 12	1.81	Apr. 6	1.67		
Sept. 17	1.37	Feb. 25	1.29	Apr. 10	1.05		
Oct.20&23	2.34	Mar. 21	1.03	Aug. 4	2.34		
Oct. 29	1.20	Apr. 6	1.12	Aug. 21	4.50		

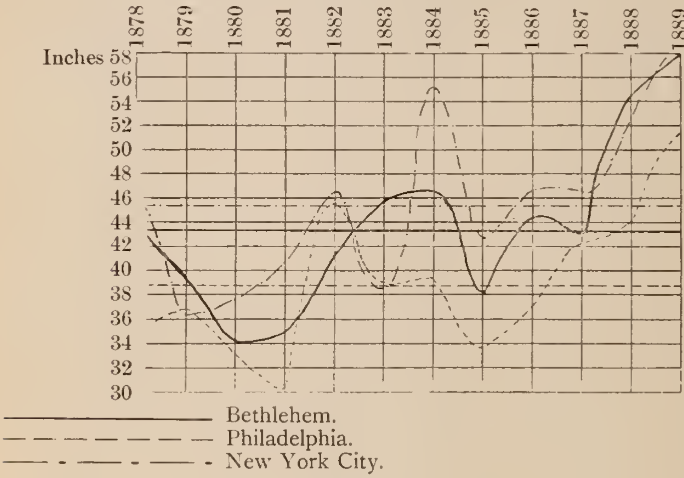
inches, an enormous fall; on August 3, 1885, 4.45 inches fell, August 21, 1888, 4.50 inches, and on September 18, 4.70 inches. On July 29, 1885, 0.9 inches fell in half an hour, and on August 3, of the same year, 3 inches fell in four hours. Mr. Pratt says: "The storm of July 29 was a mixture of hail and rain, and caused a rise in the Monocacy of five feet in 35 minutes, and in two hours it had risen seven feet, which was unprecedented."

In the Journal of March, 1886, I find the following: "On January 5 there was a freshet in the Lehigh River which inundated Sand Island and a portion of Old South Bethlehem. The water reached the height of 12½ feet above low water mark, which is greater than that of any freshet since 1869 when 19½ feet was indicated. The freshet of 1862 reached 21 feet, and the great flood of 1841 is said to have been still higher."

The following table is a comparison of the precipitation here

	1878	1879	1880	1881	1882	1883	1884	1885	1886	1887	1888	1889	Mean.
Beth.	43.83	39.33	34.01	34.99	41.38	44.93	46.36	38.11	44.23	43.07	54.67	57.68	43.55
Phila.	34.53	36.75	33.58	30.21	45.58	39.17	39.34	33.35	37.24	42.17	44.06	50.60	38.88
N. Y.	46.67	36.13	37.34	40.40	46.61	38.83	55.34	42.12	46.73	46.63	52.95	58.68	45.70

with that at Philadelphia, latitude 39°, 57′ north, longitude 75°, 9′ west of Greenwich, and of New York City, latitude 40°, 43′, longitude 75°, 00′ west.* From it and the following curve (Fig. II) we see that since 1878 Bethlehem has on an average received



much more rain than Philadelphia, but not so much as New York City, the yearly means being, Bethlehem 43.55; New York 45.70; Philadelphia 38.88.

THOS. C. J. BAILY, JR.

INVESTIGATION OF THE NEW STAND-PIPE, BETHLEHEM, PA.

The name stand-pipe is generally applied to this structure, but the height being only one foot more than the diameter, the name reservoir could be used with equal propriety.

It was built in the Fall of 1889 at a cost of about $7000. In connection with a smaller tank it is used to supply water to the Borough of Bethlehem. In the course of its erection a scaffolding, on which a gang of men were working, gave way. Two of the men were killed and several injured, The direct cause of the accident is not known, but it was probably due to the shock caused by one of the men jumping from a higher scaffolding to the lower one.

* Latitude of Bethlehem, 40° 37′ North, longitude 75° 23′ West.

The reservoir is made of iron plates riveted together, the whole resting on a foundation of masonry. The following are its dimensions:

Height, 52.8 feet.
Inside Diameter, 51.8 feet.
Plates, 10.2 feet by 4.4 feet by ½ inch.
Diameter of rivets, ⅞ inches.

Its capacity is 834,110 gallons, its weight 220,000 pounds.

Investigation for Sliding.—Using Fannings formula for wind pressure, namely $W = .5\ PA$, where P represents the pressure of the wind per square foot aud A is the product of the height and the diameter, there results, assuming $P = 40$ lbs.

$$W = .5 \times 40 \times 51.8 \times 52.8 \text{ lbs.} = 54{,}700 \text{ lbs.}$$

Let $M =$ the weight of the stand-pipe $z = .25$ its coefficient of friction on its foundation, then when $W = Mz$, sliding takes place. As Mz equals 55,000 lbs. which leaves but a very small factor of safety, the tank should be anchored. However, as the tank was filled with water as soon as it was finished, no trouble has been experienced from this source.

Investigation for Overturning.—If $d =$ the diameter and h the height of the stand-pipe, then the moment of the weight $= \frac{1}{2}\ dM$, and the moment of the wind $= \frac{1}{2}\ hW$. The former must be greater than the latter to prevent overturning.

$$\tfrac{1}{2}\ dM = \tfrac{1}{2} \times 51.8 \times 220{,}000 = 5{,}698{,}000 \text{ ft. lbs.}$$
$$\tfrac{1}{2}\ hW = \tfrac{1}{2} \times 52.8 \times 54{,}700 = 1{,}444{,}080 \text{ ft. lbs.}$$

From this it is seen that there is no tendency to overturn, there being a factor of safety of about 5.

Pressure of Water.—From the formula $pd = 4\ tS$ in which $p =$ the pressure of the water per square inch $= 0.434\ h = 23$ lbs. per square inch; $d =$ the diameter in inches $= 614$ inches; $t =$ the thickness of the plates $= \frac{1}{2}$ inch; $S =$ the working tensile strength, we obtain $S = 7{,}060$ lbs. Assuming the ultimate strength of plates as 55,000 per square inch, the factor of safety $= 55{,}000 \div 7060 = 7.7$.

As the plates are of the same thickness all the way up, the factor of safety will increase. Fanning gives as the result of a number of experiments, that a double lap joint in a half-inch plate possesses about 70% of the strength of the plate. Therefore the factor of safety of the joints is about 5. At present the tank does not directly supply the mains and is only used to store

a reserve supply of water, It is uncovered and the wind is constantly driving the water out. Without a cover and used in its present capacity it is an expensive luxury.

F. R. BARRETT.

EDITORIALS.

At the meeting of April 1st, Dr. Merriman gave a very interesting talk upon "Nationalism and Engineering." After a brief review of Edward Belamy's famous novel, the subject of Nationalism, especially in its connection with the engineering problems of the day, was discussed. The following is a brief resumé of the address.

"We can detect a growing tendency towards government control in works which, until recently, were left entirely to corporations or to individuals. The first agitation of this question occurred when the subject of river and harbor improvements began to be agitated. Should every one be taxed for what would benefit but a few, or should these matters be left entirely to the states so benefited? *Now* the subject of government ownership of canals, railroads, and telegraphs is assuming vast proportions, while Uncle Sam has actually a controlling influence over the railroads through the provisions of the Inter State Commerce Law. The tendency may also be detected in the planning of that stupendous bridge across the North River, New York, to be built under the directions of the Secretary of War.

There seems to be no doubt that it is more economical in the majority of cases for a city or town to own its water-works and lighting plant; statistics clearly show this; but just how far the reasoning should be extended when applied to the general government, is one of those problems which time only can solve.

Twenty years ago it might be called an unwritten law that civil engineers in government employ should never be given superintendents' positions, nor over $150 per month, and such is very nearly the case to-day, where we constantly see men grown gray in the service subject to the orders of some stripling fresh from "the Point." Government work under the U. S. Engineer Corps has in the majority of cases been done economically and well, there has been no known cases of the actual embezzlement

of public money, and so, notwithstanding the triumph of the civil over the military engineer, in the construction of the South Pass Jetties, and the many memorials presented, praying that Civil Engineers may be allowed to compete with the Military, Congress has at yet done nothing, and to-day, as years ago, the Civil Engineer does the work while the Military Engineer gains all the glory."

Now that the Senior Class is about tò graduate, the following words of advice received by one of them, from a civil engineer of experience and ability may not be out of place.

"You will probably make the same experience that I did, viz: circumstances will determine your career. In the abstract I would say, that railroads generally pay their engineers very poorly and dismiss them just as soon as they can. Hydraulic engineers, employed by cities to design water-works and sewers, fare generally better, but then politics often interferes with the peace of their minds. There are a great many more good railroad engineers than distinguished hydraulic engineers. . . . . If you could obtain a position on a large railroad, you might be steadily employed by that company and rise gradually to an important position. If you work for other companies (especially new ones), you will have a great many ups and downs, but you may succeed in less time. I think there is going to be a great deal of work for engineers in the near future."

These words, coming from a man well known in engineering circles, should have some weight. Every one would do well to ponder them deeply. It is a mistake to be too eager in obtaining a position. Dr. Lamberton in his parting address to the Senior Class mentioned this very thing. Weigh the pros and cons before accepting, and after you are once in, beware of the rut.

Professor E. H. Williams, Jr., has recently published, in pamphlet form, a series of problems in locating faulted beds and veins, designed for the use of the Freshman Class in Mining Engineering.

The author states in his preface that the problems cover methods of treating faults, that have been used with the higher classes in the mining school for a number of years, and that a change in the course has enabled them to be simplified and arranged as problems in Descriptive Geometry for the Freshman Class.

Although the work is of an excellent character representing practical methods of drawing as related to mining problems, we are inclined to think, after a careful examination of the book, that its subject matter is rather difficult for beginners who have never studied descriptive geometry. However, as the success of a similar plan adapted to the needs of the class in Mechanical Engineering is now well established, we may venture to assert that a similar success will result to the Mining School from this change in its course.

The pamphlet before us is very fully illustrated and is remarkably free from typographical errors.

Numerous definitions and notes appear throughout the text, and are not only an aid to the intelligent comprehension of the problems, but they directly familiarize the student with the terms used in Mining Engineering.

ALUMNI NOTES.

1869.

Miles Rock, C.E., has returned from Guatemala and is now located in Washington, 1430 Chapin Street, N. W. He is at present engaged in the reduction of observations made by him on the boundary of Guatemala and Mexico, as President and Chief Engineer of the Boundary Commission for those countries.

1874.

C. W. Haines, C. E., is at the Engineer's office of the Trenton Cut Off Railroad at Norristown, Pa.

1878.

W. K. Randolph, C. E., is with the Norfolk & Western Railroad at Roanoke, Va.

1883.

H. A. Porterfield, E. M., who was formerly Engineer of Tests for the Cambria Iron Company at Johnstown, Pa., is now at the Edgar Thomson Steel Works and Furnaces. Address, care of Carnegie, Phipps & Co., Braddock, Pa.

1888.

Chas. H. Miller, C.E., has become a partner of Mr. Wetzel of the same class. His address is Room 12, Chamber of Commerce, Sioux City, Ia.

William Bradford, C.E., was recently married to Miss Sophie Wilson of Wilmington, Del.

S. W. Frescoln, C. E., is on the Engineer Corps of the Norfolk & Western Railroad, Ronald, Montgomery Co., Va.

1889.

Chas. H. Deans, C.E., is at Needles, Cal., where he is engaged in the erection of a cantiliver for the Atlantic & Pacific Railroad across the Colorado River.

R. P. Barnard, C.E., has become Assistant Cashier of the Mutual Trust Company, Washington, D. C.

1890.

Alexander Potter, C.E., having completed his course at the University, has returned to Halifax, N. S., of which city he was recently appointed Assistant Engineer.

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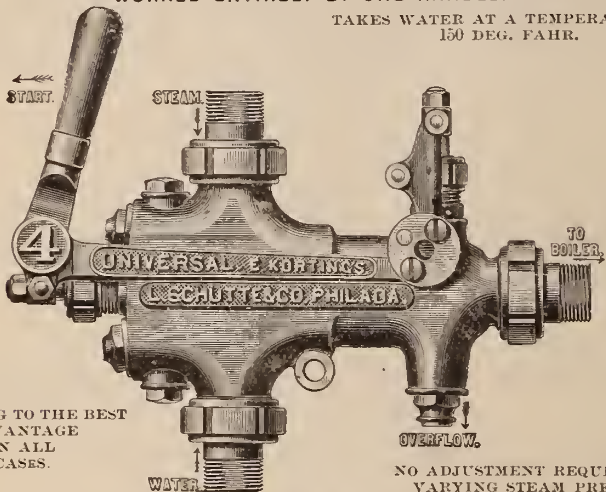

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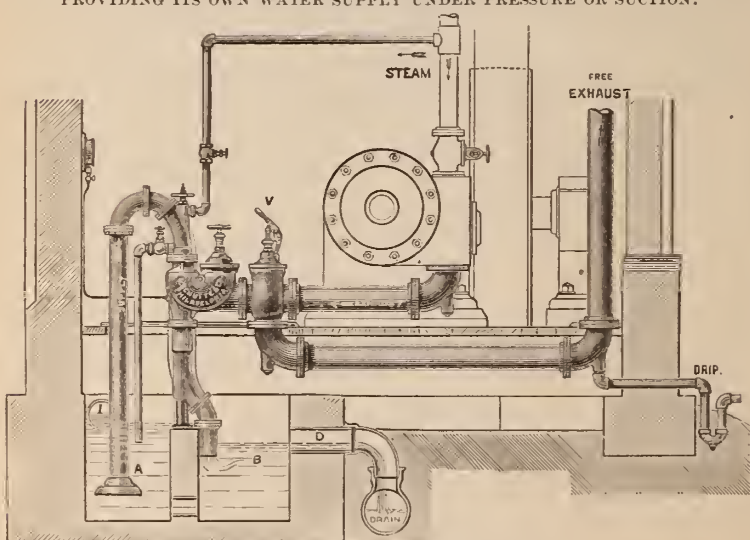

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